Team 15 Knight-Cut

Senior Design 2017-2018

Calvin College ENGR339/340 Senior Design Project

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Abstract:

Knight Cut is an industrial application that looks to automate the hose cutting process currently in place at MFP Automation Engineering, an automation company in Hudsonville Michigan. Our machine utilizes a rotary encoder, 2 conveyors, electric motors, pneumatic cylinders, and an array of other components in order to measure and cut steel wire reinforced hydraulic hose lengths to an accurate distance. Our machine is capable of feeding, measuring, and cutting hose lengths ranging from 5" to 150', with sizes ranging from #4 (¼" ID) to #20 (1 ¼" ID). Our system uses a 24V DC supply voltage for the logic element of the circuit, with an input power supply of 230 3-phase AC. Overall our project was a success, aside from the fact that we did not receive all our components in time due to shipping delays. The components that we did receive we were able to place into the system and performed as intended.

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1. Introduction

The goal of our project was to design and construct an automatic hose cutting machine for the company MFP Automation Engineering. Team organization and communication with the customer was critical for this project in being successful. Our team had to schedule and budget both time and resources efficiently to guarantee the project was done by early May 2018.

The project opportunity arose as a team member was approached by MFP Automation Engineering to help upgrade their current cutting process for steel reinforced hydraulic hoses. Currently, the process is labor and time intensive. As it stands, when there is an order for a hose (or multiple hoses), the process follows the flow depicted below in Figure 1.

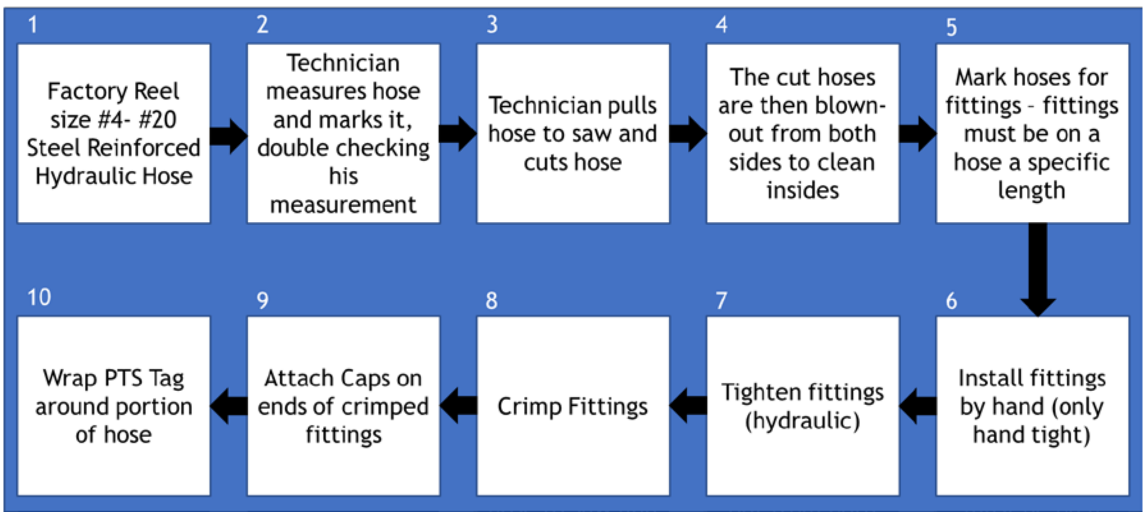

Figure 1: Flow diagram of current hose cutting process at MFP Automation Engineering.

Above, in Figure 1, is a simplified block diagram of the existing base assembly process. There are procedures happening outside the scope of our project that could easily be upgraded; however, these processes are not the goal of our machine.

Our goal was to take the flow diagram depicted in Figure 1 and simplify it to the flow diagram depicted in Figure 2. Figure 2 shows the new hose assembly process with our machine implemented into it, which takes the measuring and cutting processes away from the technician. This allows for the technician's time to be better utilized elsewhere. Currently, measuring and cutting are the most time and labor-intensive pieces of the hose assembly process. Our machine drops the 10-stage procedure, seen in Figure 1, to 8 steps. The hose cutting process was analyzed to see how much time would be saved by removing the cutting and measuring phases. By taking data for how long it takes a single hose length from taking the hose off the reel, measuring, cutting, cleaning, and marking, the average time for each hose length was determined to be 36 seconds. By removing the cutting and measuring steps from the process, the average time would take 22 seconds. This means that 15 seconds is saved per hose length which is a 60% increase in productivity. Figure 3 below illustrates this analysis.

Referring to Figure 2, the previous stages of 2 and 3 within Figure 1 have been removed. Once the proper hose size is in place, the technician only needs to input the parameters of the order: hose size, length, number of pieces, length of factory reel. After parameters are entered, the technician can walk away from the machine while it runs. This process is then repeated if the order requires varied sizes of hose. Sizes of hose can range from 0.25" ID (size 4) to 1.25" ID (size 20).

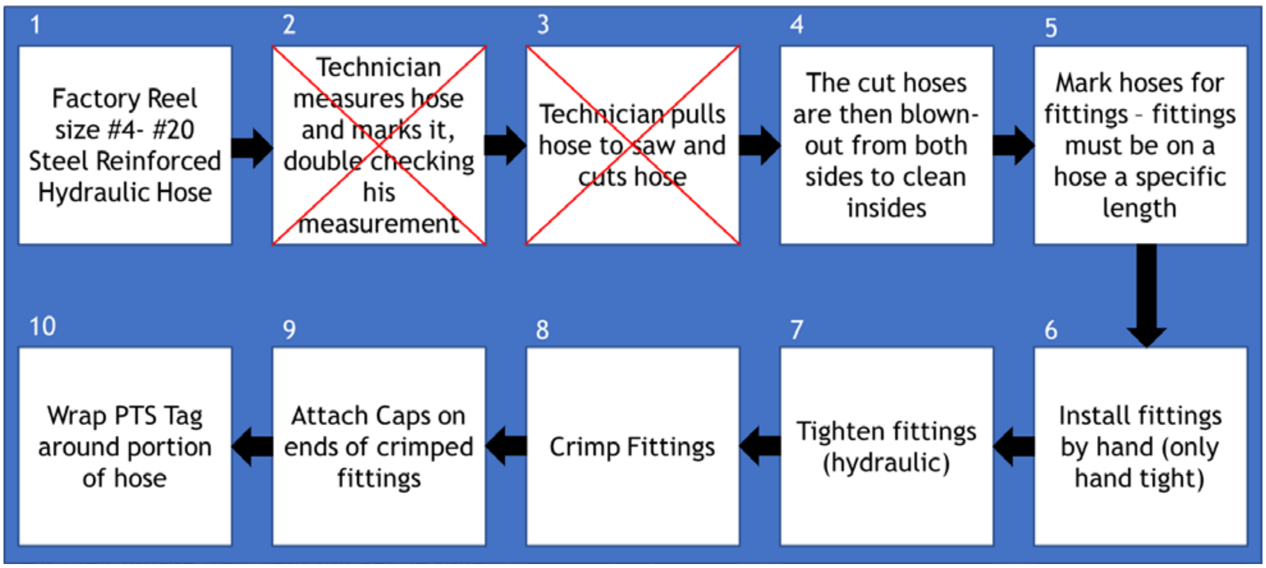

Figure 2:Flow diagram of projected hose cutting process in place at MFP Automation Engineering, after our machine is implemented.

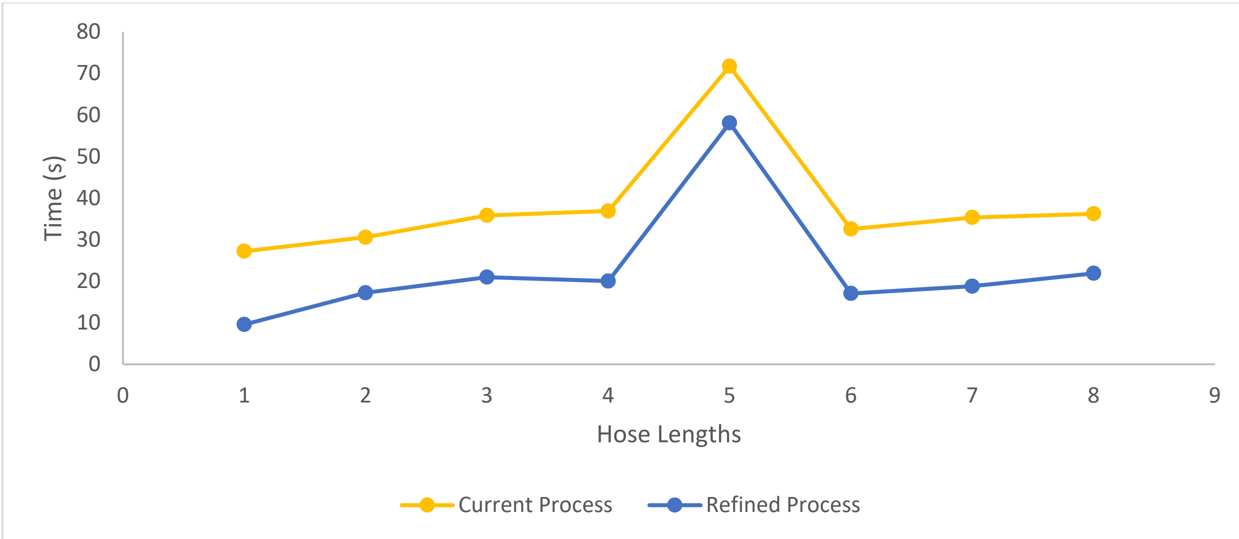

Figure 3: Data Analyses of removing the cutting and measuring phase

1.1. Opportunity

Our team had the opportunity to help improve the hose assembly process for MFP Automation Engineering. They approached our team with an idea of automating steps within the assembly process. After a lot of discussion with team members and MFP Automation Engineering, it was decided that the scope of our project would be to eliminate the most time-consuming steps within the process: measuring and cutting phases.

Our teams focus for this opportunity was to create an automatic hose cutting machine that targets the cutting process specifically. This required confirming a clean 90^{O} cut as well as implementing the appropriated safety measures. Factors that helped our team succeed in creating a working prototype were maintaining trust, having integrity, and always staying humble.

Trusting in each of our teammates was key. MFP also trusted us to provide a dependable and reliable machine that met the requirements they had set in place. Without trust, there was no opportunity. The integrity of each team member was also significant, as our team had a transparent relationship with each other and MFP. With this good relationship, our team had excellent communication and unity. Additionally, each team member stayed humble throughout the project. Our humble attitudes allowed for us to work more productively and allowed us to take healthy criticism from our college advisor, industrial advisor, and vendors who provided us parts. Staying humble allowed us to use MFP's resources conservatively, while still fulfilling the purpose of this opportunity.

To conclude, our team designed and prototyped a machine that would feed hose from the hose reel into our machines hose cutting area, where a pneumatic cylinder would push down onto the hose and into a rotary blade. A rotary encoder was used as our machines measuring mechanism, which allowed for the accurate and precise length measurements we needed.

2. Project Management

2.1. Team Organization

The team was made up of two mechanical engineers (Mitchell and Reuben) and two electrical engineers (Peter and Lars). Having both mechanical and electrical engineers within our team allowed us to split up tasks well into smaller teams based on what the task was. Our team knew the strengths of each individual, which allowed us to utilize each team member skills appropriately. Lars oversaw the schedule, website, and the controls system with Peter. Peter was in charge of ordering parts and acted as our teams project manager. Mitchell oversaw meeting minutes and documentation while Reuben oversaw the budget and research. Mitchell, Reuben, and Peter oversaw the design layout of each mechanism on the machine.

However, after all is said, each team member collaborated with every task. No teammate was ever left alone doing a specific task in which needed to be done, we always worked as a unit. Team work allowed us to effectively meet deadlines and grow as lifelong friends.

2.2. Schedule

The scheduling was managed by Lars. Throughout the second semester, there were some minor changes made periodically due to obstacles that would present themselves. One thing that turned out to be a major issue that threw a wrench into our schedule was logistics. We did not give ourselves enough time when ordering specific parts. A few the parts we ordered had lead times longer than what was promised by our vendors, which caused us trouble down the stretch of our project. We also experienced troubles with MFP’s shipping and receiving department, as many of our parts happened to get lost there. Overall, the number one thing that this has taught us about making schedules is to leave enough time for all the parts to come in. We learned that logistics hurt the project immensely.

2.3. Budget

The budget was managed mostly by Peter and Reuben. MFP Automation Engineering was our sponsor for this project. They provided us a budget of $10,000; however, our teams goal was to use closer to $7,000. We were on track to be close to our goal but we heavily underestimated the expense of our conveyor system. The actual cost of the project was roughly $8,882.65. We went over our original goal but succeeded in staying under $10,000. The detailed budget is shown in Appendix B along with all purchased parts and their value as well as donated parts and the value they would be worth if they were purchased.

3. Specifications

3.1. Cut Length

Cut length was the first of our specifications, as MFP provides a large range of hose sizes to customers. The maximum hose length that MFP Automation Engineering wanted our machine to be able to cut was 150 feet long, while the minimum length was set at 5 inches. Meeting these ranges of hose lengths allowed MFP to continue providing customers with a variety of hose sizes. Some of MFP's customers use these hoses for medical applications and therefore the tolerance of the cut was very small. Each hose must meet the required stack up tolerance of .5% per unit length to be considered a usable part. The accuracy and range of the system will be tested by running the machine through the full range of hose lengths in intervals. We will then measure the cut hoses to make sure they are within spec. Using a stack up as a tolerance means the shorter lengths will be more precise than the longer lengths due to the potential stack up. Also, when dealing with the longer length hose the length can get rougher due to the impact of a few inch on the entire hose and often has a little amount of wiggle room.

3.2. Hose Size

Our machine was designed for a large range of hose cut lengths as well as being able to handle a variety of hose sizes. MFP provides a larger range of hose sizes to their customers than our machine is capable of handling, as we can only handle sizes ranging from ¼ inch hydraulic hose (size 4) to 1 ¼ inch hydraulic hose (size 20) inside diameter. Our saw has the ability to cut the largest size of hose without being destructive to the smaller, flimsier hydraulic hoses. The feeding and tensioning system were designed for easy adjustment in order to cover the wide range of sizes needed. To test that our machine worked for the given range, we ran various hose sizes through our machine being sure that the product performed as expected with each size. We found that the hose sizes in the middle of our range (#10 or $^{5}/_{8}$”ID, and #12 or ¾” ID) performed the best.

3.3. Mobility

Another specification that was crucial in meeting MFP’s needs was mobility. MFP wanted the machine to have the ability to be moved around the shop. This was mainly because not all hose reels are placed in the same area. Additionally, our machine is able to connect with a standard shop power outlet of 230V AC and to regular shop air at 90 PSI. To have the machine mobile, the machine was built using a cart as its core body. The cart also has a brake on it so that when the machine is running it won’t move, which would cause a safety risk.

3.4. Cut Quality

The final specification presented to our design team was the quality of the cut. This is essential to MFP's business. To produce a clean finished cut, it must be at 90°. The margin of error that is tolerated in the industry is +/- 3° , which is quite precise considering how flexible the hoses can be. The hose must be cut square so that when the fitting is placed on the end, the fitting makes a complete seal. If it is cut at too severe of an angle, the fitting will wear much faster due to improper sealing and will become a safety hazard, especially at higher pressures.

4. Design Alternatives

4.1. Design Ideas

<u>Cutting Method</u>

When deciding how we wanted to cut steel reinforced hydraulic hoses, our team had to determine the risks and rewards that go along with each alternative. The most important aspect of the machine is to create a clean cut on the hose due to safety risks. When hoses are used in the field, if they do not have a clean cut, the risk of the hoses failing increases significantly, which increases the risk of injury to a person or equipment.

The first cutting option for our machine was to bring the saw into the hose, which would be fixed in place. Although this method seems ideal, it has safety and financial risks attached with it. Having the saw move into the hose means that the machine will not only have a rotating saw, but one that is moving up and down. This increases the chance of injury if an employee is not careful. Moving the saw into the fixed hose would also cost MFP financially, as the blades would have to be replaced more often due to heavier wear and tear from the hose. The heavier wear and tear on the blade would be caused from hoses not being flexed properly while being cut, causing the blade to pinch the hose, which would also make the cut less clean.

The second cutting option for our machine would be to bring the hose into the saw, which would be fixed in place. This option allowed for the hose to have a bend, allowing for the hose not to pinch the blade as makes contact. Additionally, the cut of the hose will be much cleaner due to no pinching, which will also allow the blades to have a longer lifecycle. This option is financially and mechanically preferred; however, it still has the risk of potential injury. Safety was always a risk that our team assessed.

The third cutting option for our machine would be to use a guillotine to cut the hose rather than a rotating saw. The problem with this method was that by using a guillotine our machine would need to produce a lot of force on the hose to cut through the steel. Additionally, if the guillotine had enough force to cut the hose, the blade would likely be pinched causing a messy cut with a frayed end. As said before, not having a clean cut increases the risk of failure of that hose in the field, which increases the risk of injury or death of a person. This method had more risks than rewards in our team's eyes.

The cutting alternative that our team determined best was option two: bringing the hose into the saw. This method had the lowest amount of risks within it as well as the highest amount of rewards. It made the most sense to our team that we implement this method, as it allowed us to focus in on making a clean cut, which was the point of emphasis of the machine.

Feeding System

The method in which we feed the hose to the saw was important for obtaining the accurate amount of length. The feeding system had to be able to accurately bring a wide range of hose lengths and diameters to the saw. The difficulty in this, was that the feeding system needed to be consistent across the whole range of hoses. From research, we learned that a popular feeding system was a double conveyor system that would push the hose to the saw. This system is pictured below in Figure 3. This method is popular because it maximizes the amount of surface area that the hose is in contact with which will minimize the amount of slippage. We decided to implement this system. The risk with this system is that it was difficult to think of how we would obtain the full range of hose diameters since each time the hose size changes, the height of the conveyors would also need to be changed.

Figure 4:Conveyor Feeding Mechanism

A pulley system driven by belts was also considered as an option; however, we don't believe that this system will be ideal for feeding because there is a much higher risk for lower amounts of accuracy. This is because there is more slippage expected within this design due to more forces acting on the hose to keep it in tension and less surface area from the pulley's connecting with the hose. The benefit from this machine is that it would reduce the amount of elastic rebound from the hose, which would be trying to return to the shape of the hose reel.

Another alternative was to leave the measuring system manual. This involved changing nothing from the current process or inputting a hand crank system. The reason to implement this alternative would be to focus entirely on automating the cutting aspect. However, measuring and cutting are so intertwined that this alternative was rejected.

The final alternative was to create a conveyor system that had clamps to attach to the hose. These clamps would clamp onto the hose as it came around the belt and release the hose as it got to the end of the conveyor to start another rotation. There would be multiple clamps so that one is always pulling the hose. The risk involved with this system was the timing between when the clamps should be clamped and released would be very difficult for each individual clamp. Additionally, another risk was that if the clamp happens to end up under the blade due to a needed measurement, we would have the potential to damage the system and lose accuracy. The reward for the system is that there would never be any slippage and the system would be extremely accurate.

Hose Measuring Method

Measuring the length of hose needed to be cut was the biggest challenge of our design. This was due to the very small tolerances that were required. The first design system that we thought about was a vision system. This system would be able to measure the length of hose based off the number of patterns counted, which are factory printed specific to the manufacturer. This system would be difficult to implement since the hose would likely spin throughout the process. If the hose spins the vision system would be unable to have continued sight to the product pattern and lose its accuracy. Therefore, we opted not to use the vision system.

The second alternative we looked at was using a loop controller to measure the hose length. This system was different in the sense that it doesn't necessarily measure the hose specifically, but instead uses a formula relating output feed from the conveyor system and the amount of time passed since the previous cut. The loop controller measures the output of the hose from the conveyor belt, compares it to the feeding rate of the conveyor belts, and then adjusts according to the error involved. An illustration showing this process is pictured below in Figure 4

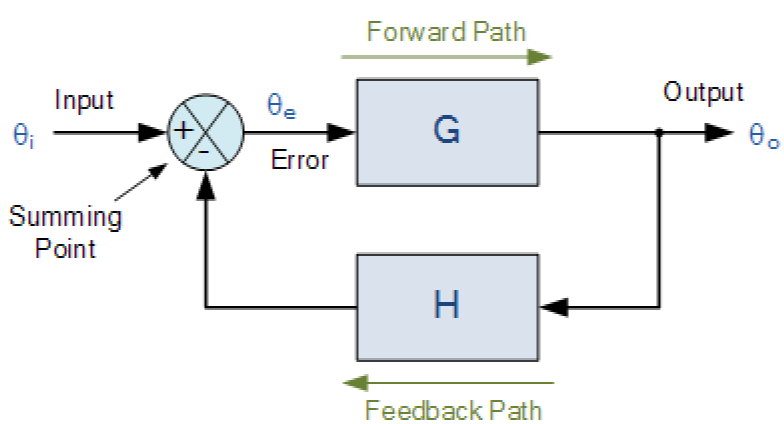

Figure 5:Closed-Loop Controller diagram

The final measurement alternative considered was a rotary encoder. This consists of a disk that has a series of different magnetic poles built into it. The encoder is designed with a CPR (cycles per rotation) which is then factored in when figuring out how far you have gone on the encoder. The encoder will then be mounted to a gnarled wheel which will be in constant contact with the hose preventing slippage. The major risk involved with using a rotary encoder is the fact that there must always be physical contact between the encoder and the hose. We decided to use this method in relation with our tensioner system, to measure the amount of slack in the system. Since the hose is in tension, forcing constant physical contact was much easier to obtain. Similar systems can be found in other machines that do a similar process with a similar tolerance range.

<u>Spool Mount</u>

The spool mount is an important part of the system which ensures that the feeding system doesn't get over fed and gets extra hose in the system when stopping, or have the reel back feed and pull hose away from the saw. This could affect the accuracy of the length and the quality of the cut.

The first method was to have a rotary dampener on the spool mount which would make it hard to move in either direction. The plus to the method was that it is practical and is guaranteed not to allow any extra hose go into the system. The downside is that the dampers could only do about 12 RPMs and that is not nearly enough speed to have a realistic takt time.

The second method is a clutch bearing. This would allow free spin in one direction but not the other. This would give us the RPM that we would need for a realistic takt time but they only work in one direction and we are worried about the spool free spinning in both directions which then made the part impractical for our design.

The final method is a brake. This would allow free spin in both directions when feeding but can then stop the spool from spinning when the system is cutting. We decided to do this is through the use of a jam brake with a pneumatic cylinder shifted by an electric solenoid. The brake had a custom head that when energized put friction on the spool, stopping it from interfering with the other processes.

<u>Control System</u>

The control system for our design consisted of a few alternatives. Our focus when considering a controls system was the power and the robustness of the system. A major aspect we considered when it came to the systems power was that the control system needed enough power to turn on the motors for both the feeding and cutting system. Additionally, a second aspect which needed to be considered was the robustness of the system. Because our system is going to be used in industry, our team needed to make sure that the system would last.

The first option was a PLC controller with HMI interface. The benefits of this was that it is widely used across industry and used in most automated processes showing the capabilities of common PLC's. This is also the system that MFP is most familiar with using, making it easier for them to modify and add to in the future. The problem of the PLC was the cost of the controller, but overall the PLC was the best controls system option for our design.

The second control system option considered was a Raspberry Pi with keyboard and screen. The benefits of this control system were that it is cheap and has a lot of open source coding; however, the system doesn't respond great in real time with information from sensors. This component is like a small computer, allowing it to perform complex activities. Other issues with Raspberry Pi were that it is not widely used in industry and although it can run complex programs, the system that we are using doesn't need that complex of a program in order to run.

The last control system option was an Arduino board with a keyboard and screen. The benefits of this control system were that it is cheap and has a lot of open source coding. The system is a micro controller with a fast response time; however, it only uses simple programs. The problems with this system were that it is not as robust as the PLC controller and MFP will need to develop infrastructure around it for support, as opposed to the PLC, which already has infrastructure around it. This made the PLC controller most preferred in the long run, as it is the best control system for industry and therefore for our project.

4.2. Final design Choice

The final design choice was decided based off the design alternatives that best fit the opportunity presented from MFP. Our team designed our cutting process to bring the hose to a stationary saw. This alternative was chosen because it was much easier to implement a safety feature for the saw if it is stationary. Bringing the hose to the saw provided a cleaner cut since this method provides a bend radius in the hose, restricting any pinch point on the blade.

The feeding system we chose to pursue includes a tension system in combination with the conveyor belt. The tensioning system will not only straighten out any kinks in the hose, but also aligns it with the conveyors and the saw. The tensioner consists of two v-rollers, which sandwich between the hose. The hose will then feed into the conveyor belt system. This transition allows for some slack in the hose, so that when the feeding system stops to get cut, there will be less strain on the components when it slows down. The conveyor system can feed at a set rate and is a variable in the measuring system. The top conveyor system is adjustable by using two half inch threaded shafts that are connected to another plate with bearings. At the top end of the shafts, there is a handle for easy adjustment, allowing a simple and short set-up time.

The measuring method implemented was a rotary encoder. The rotary encoder is mounted on the tensioner stand, where it is adjustable and is always in contact with the hose. This allows for us to obtain an accurate and precise measurement. After each cut, the measuring system is "zeroed" and the process begins all over again.

Additionally, we have a pneumatic cylinder that presses into the reel shaft acting as a jam break. This brake is used to stop the reel shaft from rotating back or forward after the conveyor system is done feeding the hose into the cutting area.

The Control system we implemented was the PLC and more specifically the Exor 705 PLC with HMI directly on the unit. The PLC was given to us by the company because it is a new to the industry and stood as a "show point" for MFP. The Exor 705 has the capability to be modified and expanded to accommodate any new parts or processes, or integrate with the other systems. The HMI is also easily modified and can be upgraded via an ethernet port to any laptop with appropriate software. The PLC also the new feature of a capacitive touch screen allowing for scrolling and zooming making the HMI more practical and advanced for future uses, as opposed to resistive touch screens with only tap capabilities.

4.3. Testing and Debug

For the Testing done the separate parts like the PLC, conveyors and cylinders has been tested and proven to work. The test for the cylinder was simple to set up the regulator, hose controller, and cylinder. Then hooked up the control wire with a power supply which showed the extending and retracting. The conveyors were tested by hooking them up to a DC driver and then testing the various speeds along with forward and reverse control. The next step was mounting the systems and test to see if the same things happen when a hose is introduced to the system. The PLC testing is simply setting up the HMI and testing to see if the various field allow input and send data to the right variables.

5. Safety

Safety was a major issue our team had to think about when creating our machine. We had to be conscious of safety when designing a system so that we could limit the amount of risk involved with our machine. The three main safety issues we were concerned about with our machine was the saw, the toxins released from cutting the hose, and the cumulation of moving parts in the system. The saw is the most injury prone device. In fact, an MFP employee cut off multiple fingers in a past incident while using the same saw we utilized within our machine. Our design for the saw has a safety guard over the blade so that there is minimal room for anything but the hose to be pushed into the saw. Our set up requires a person to deliberately place fingers or objects beyond the blade enclosure, and even then if a hose is present there is almost no room for anything to get past.

The toxins released from the coating of the hose, during the cut, was also an issue we had to keep in mind while designing. What would happen if employees were subject to long term exposure? MFP's existing saw has a large hood placed directly behind where the saw is mounted, allowing for the soot to be vented and filtered out of the area. This method is works effectively at disposing the toxins out of the building. Our goal in this design is to utilize that vent primarily, but in addition, we have left room for future implementation of adding a shop vacuum system within the saw enclosure. This would allow the rubber emissions to be better regulated but would also help catch the rubber debrief from the portion of hose that is cut.

All the other moving parts in the system that have the potential to catch a loose piece of clothing or hair, must be guarded to mitigate any injury. As an additional safety feature, we have an emergency system shutdown mechanism (E-Stop) that will stop the whole machine from running. We even thought about adding a safety feature in which if the saw enclosure were to somehow be opened when the system is running, that the system would automatically shut down. However, this was outside of our scope. Lastly, we planned on providing an adequate outline for O.S.H.A. approved "Lock Out Tag Out" consisting of energy control procedures. This was to ensure that before any employee performs any servicing or maintenance on the machine where the unexpected energy, startup or release of stored energy could occur, the machine could be isolated from the energy source and rendered inoperative. This was outside of our scope but is necessary for MFP to be allowed to use the machine. This was one task that our team did not get too and is a definite must for future improvements on the project.

6. Business Plan

6.1. Marketing Study

6.1.1. Competition

During our research phase of the project, our team discovered that there are similar machines available on the market that measure and cut steel reinforced hydraulic hose. We discovered that these machines were limited in certain tasks that it could perform. Most of the limitations involved being able to cut a range of hose diameters with one machine. Being able to cut a range of hose diameters from ¼ - 1 ¼ inch was one of our requirements that we had to meet. Additionally, we determined that many of the hose cutting machines available range between the cost of $20,000-$70,000. This made our team re-evaluate each system we had planned to implement to help make sure that our spending was reduced to the lowest amount possible, being that our team had a limited budget of $10,000.00

Furthermore, our team obtained a quote from a hose cutting machine supplier called Uniflex. There product, the Uniflex EM 115.3, costs around $14,000 and can be seen below in Appendix D. Specifications for the Uniflex EM 115.3 and another similar product can also be found in Appendix D.

MFP Automation Engineering recently has bought a hose cutting machine from Uniflex that uses a wet saw application. Due to the wet saw application, the machine cost them $60,000. We were very pleased with our machine due to creating it with a much lower budget than $60,000.

7. Conclusion

To conclude, our team reached our goal of designing and prototyping a machine for MFP Automation Engineering. Our product feeds hose using a conveyor system that pulls stock off the reel, moving it into the machines cutting area. As the conveyors feed the hose, a rotary encoder is mounted after the tensioning system, where it is in constant contact with the hose. After the hose reaches the cutting area and comes to a stop, a pneumatic cylinder, with custom tooling, pushes the hose into the saw blade that is beneath the top of the cart within an enclosure.

Additionally, we are still waiting for the rotary encoder and the saw motor to arrive in shipping and receiving. MFP Automation Engineering will be able to test the cutting and measuring of the system when both arrive. Overall, throughout this project our team learned that the logistics of parts is longer than what you expect, how to take healthy criticism from others, build time takes longer than you think, and how to communicate as a team, managing our time wisely.

8. Future work

After completing our project, we have determined areas of which could be improved and ideas which could be added to the product to make it better. Below is a list of future work that could be implemented into the project. The ideas below were outside of our project scope.

- ERP(Enterprise Resource Program) Interface: MFP Automation Engineering would enjoy having the machine interface with the ERP system currently in place. This means that a second stage of code would be implemented into the PLC, making it possible for our machine to interface with the ERP system, and pull data from within MFP's orders. What this means is that they could use either a specific work order number or barcode to give the system all the necessary parameters of a job. This would mean that it would recognize the hose lengths needed to be cut and the quantity of cut hoses.
- Rotary Table: Originally part of the main design scope, MFP wanted to be able to implement a rotary table, which would coil the larger lengths of hoses that would be cut using our system. This challenge would have caused us problems with the amount of time our team had to complete the project.
- Emissions Vacuum: Like previously stated before in the safety section, there will always be bad emissions that come from cutting the hose. One way to reduce this would be to add a vacuum that is attached to the blade enclosure underneath the table. This would help reduce the amount of emissions and also prevent small pieces of debris from flying everywhere.
- Debris Tray: Adding a removable tray at the bottom of the blade enclosure would be an easy addition that would be helpful for when too much debrief builds up. Essentially, a worker would remove the tray when the enclosure had enough build up and could replace it with a clean tray.
- Magnetic Lock: Like mentioned earlier in the safety section, there is an opportunity to create a safer machine by implementing a magnetic lock sensor on the saw blade enclosure, in which when the enclosure door opens the machine would shut off.

9. Acknowledgements

First off, we are thankful for MFP Automation Engineering for their financial and logistical support, helping provide the necessary guidance concerning our projects implementation. Specifically, industrial mentor and manager Scott Wanta, who helped to the give the project footing and lead the project at MFP Automation Engineering. We would also like to thank Nate Hinkle, an Automation Engineer at MFP Automation Engineering, who helped point us in the right direction for picking out the best products and processes to use for this project. More specifically, he helped direct us on which PLC we wanted to use for our controls system.

In addition, Tim Beute was an enormous amount of help within MFP's shop, helping with welding, plasma cutting, and brainstorming in the debug phases. We would also like to give recognition to Bobby Rusho, a general manager at MFP who helped us with the ordering of all our parts.

We would like to extend a thank you to Professor Renard Tubergen, whose guidance and technical knowledge helped to keep our project moving forward. His guidance in project management and his technical expertise were instrumental in the completion of this project and would not have been probable without his support. Our gratitude also extends out to Phil Jaspers, Calvin Colleges shop supervisor, as his knowledge using machinery helped us immensely.

Without their superior knowledge and experience, the project would've lacked in quality. Every person's support has been essential to our project.

Nevertheless, we express our gratitude toward our families and colleagues for their co-operation and encouragement, which help us complete this project.

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1. Appendices

1.1. Appendix A: Schedule

Table 1: Task List

Task Name	Duration	Start	Finish	Resource Names
Day 1 begin of Spring Semster	2 days	Mon 1/29/18	Tue 1/30/18	Start
Cutting design	10 days	Mon 1/29/18	Fri 2/9/18	Mitch
Motor, Plc, and Saw	5 days	Mon 1/29/18	Fri 2/2/18	Mitch,Peter
overall design	35 days	Mon 1/29/18	Fri 3/16/18	Mitch
Cutting control	10 days	Sat 2/3/18	Thu 2/15/18	Lars
control input output	32 days	Tue 2/6/18	Wed 3/21/18	Lars
Feeder Design	10 days	Thu 2/15/18	Wed 2/28/18	Reuben
measure system reasearch	10 days	Wed 2/21/18	Tue 3/6/18	Peter
Feeder Control	10 days	Thu 2/22/18	Wed 3/7/18	Lars
Tensioner Design	10 days	Wed 2/28/18	Tue 3/13/18	Reuben
Tensioner control	10 days	Tue 3/6/18	Mon 3/19/18	Lars
assembly	25 days	Mon 3/12/18	Fri 4/13/18	Rueben
measure system Design	20 days	Wed 3/14/18	Tue 4/10/18	Peter
order parts	3 days	Fri 3/16/18	Tue 3/20/18	Rueben
Controls wiring	4 days	Wed 4/4/18	Mon 4/9/18	Peter
Layout Placement	4 days	Wed 4/4/18	Mon 4/9/18	Mitch
Controls testing	15 days	Mon 4/9/18	Fri 4/27/18	Peter
Senior Design Night	2 days	Sat 5/5/18	Sun 5/6/18	End

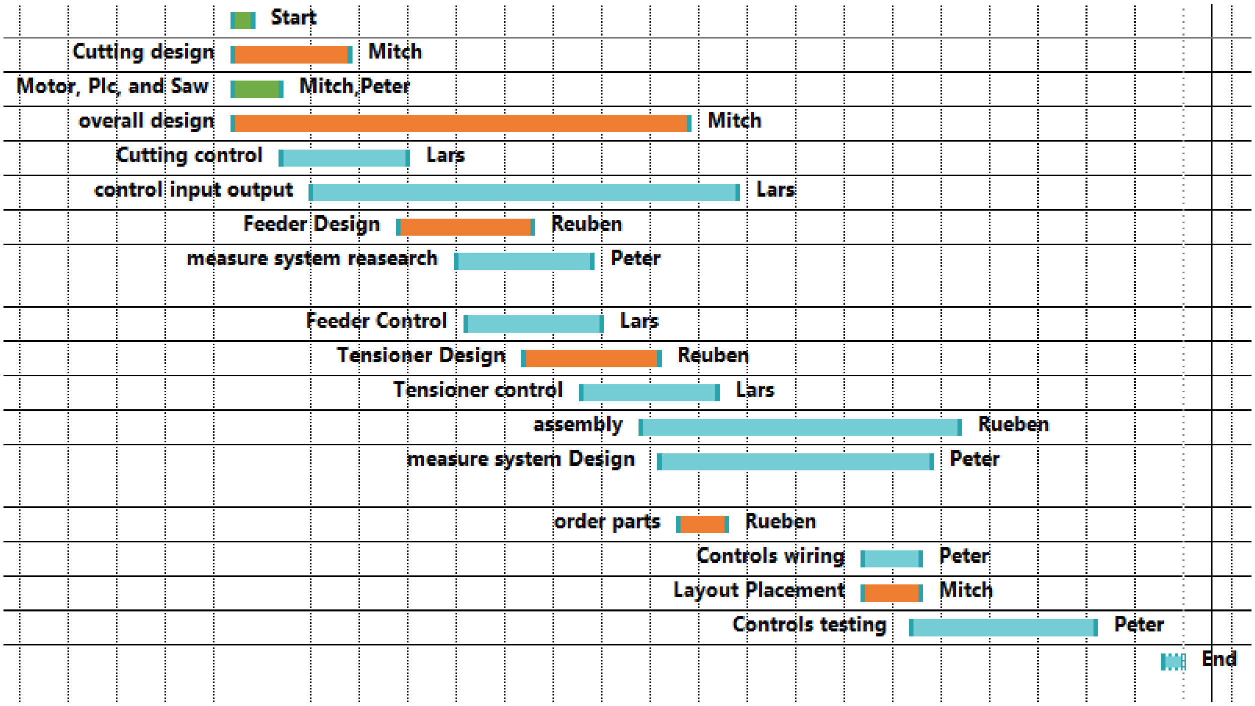


Figure 1: Gannt Chart

1.2. Appendix B: Budget

Table 1: Large Order #1

SHELF COMPONENTS	QUANTITY	PRICE	Total	Product Code
1/4-20-1"	3 PKG	$ 5.12	$ 15.36	92196A059
1/4-20-.75	1 PKG	$ 3.13	$ 3.13	92196A060
2" x 1" STEEL TUBING	6'	$ 13.97	$ 13.97	10120
2.5"x 2.5" STEEL TUBING	6'	$ 53.03	$ 53.03	6527K414
V-rollers	7	$ 30.14	$ 211.00	Quote
UMHW	6*6*6"	$ 159.25	$ 159.25	Quote
Love Joy Coupling Piece	1	-	-	L075-5/8X3/16K
Love Joy Coupling Piece	1	-	-	L075-3/4X3/16K
Love Joy Coupling Piece	1	-	-	H075
10" Saw Blade	1	-	-	
3 HP Saw Motor	1	$ 260.00	$ 260.00	53DE15
Automation				
ex705	1	$ 829.00		
Parker AC10 Variable Freq Drive	1	$ 341.00		
Ball and screw actuator	1	$ 200.00		
ELJ Enclosure	1	$ 119.20		
ELJ Enclosure (for saw blade)	1	$ 53.05		
Conveyor Belts + rotary encoder	1	$5,266.65		
Parts Ordered on:	TOTAL	$7,524.64		
DATE: March 20, 2018				

Table 2: Large Order #2

SHELF COMPONENTS	QUANTITY	PRICE	Total	Product Code
Pillow block bearing @ 3/4 in diameter	2	$ 70.83	141.66	F4BSC012
Pillow block bearing @ 1/2 in diameter	2	$ 46.66	93.32	F2BVSC008
Pillow block bearing @ 2 in diameter	1	$ 156.17	156.17	P2BSC200
Hex Nuts @ 1/4 in diameter	2 bags	$ 4.80	9.60	41FT96
Bolts @ 1/4 in diameter @ 1" length	2 bags	$ 3.76	7.52	584
Bolts @ 1/4 in diameter @ 3/4" length	1 bag	$ 3.31	3.31	583
Motor Vibration Isolater	1 pkg	$ 7.87	7.87	361X078
2*1 steel rectangular tubing	60"	$ 23.50	23.05	-

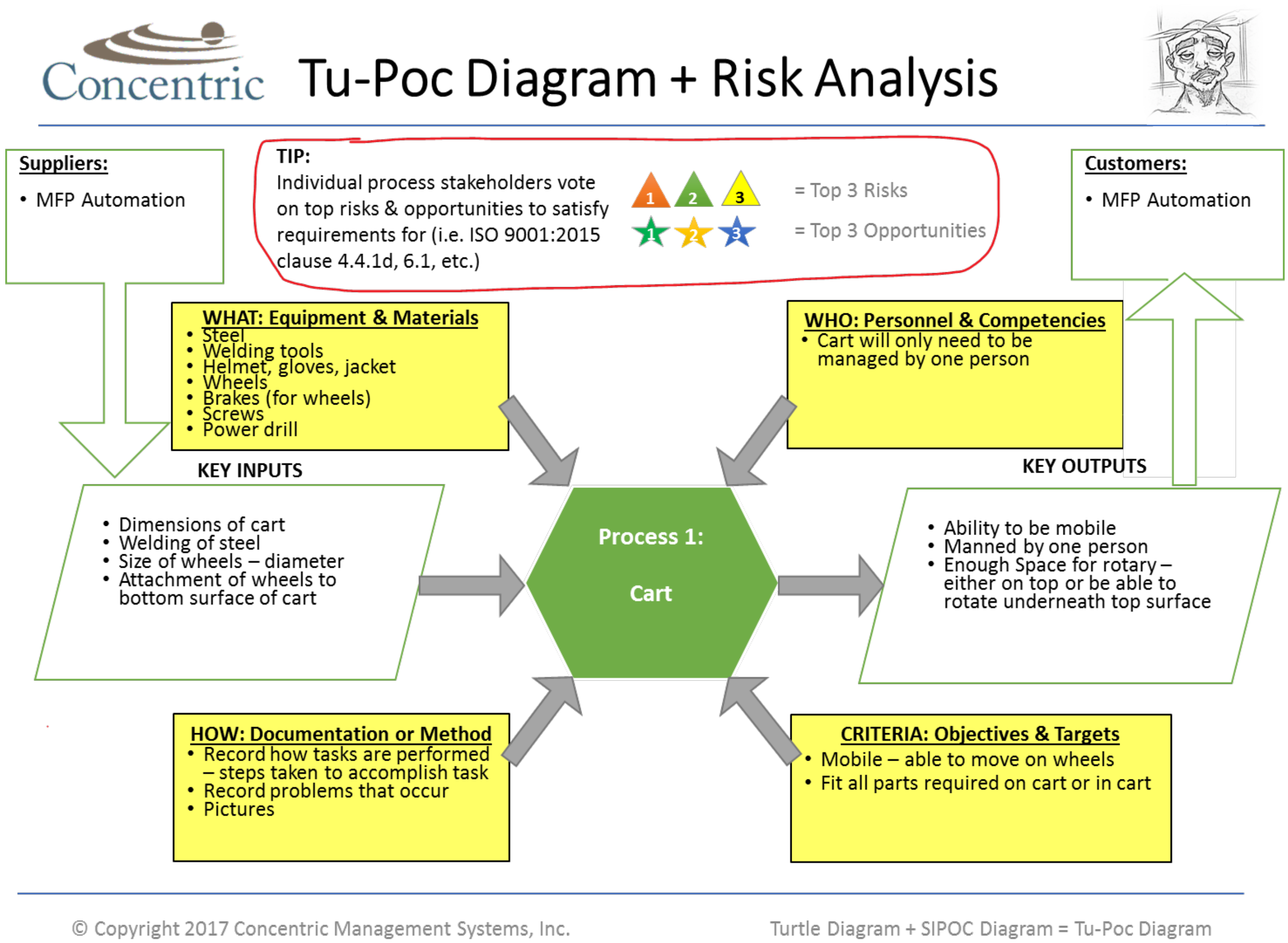
Automation Parts	QUANTITY	PRICE	Total	Product Code
Rhino power supply	1	$ 59.00	59.00	PSB24-060s-3
Motor Protector for Saw Motor	1	$ 96.27	96.27	XTPR004BC1
Motor Protector For Conveyor Motor	2	$ 96.27	192.54	XTPR6P3BC1
Exhaust filter	1	$ 11.00	11.00	efa100r5
Main Circuit Breaker	1	$ 25.25	25.25	FAZ-B15-3
2 CONDUCTOR FUSE DISCONNECT FOR 5X20MM FUSE	1	$ 9.16	9.16	2006-1611
10A 250V Fast Acting 5X20mm fuse	1	$ 2.62	2.62	GDB-10A
Socket with Miniature Switching Relay	10	$ 7.86	78.60	857-304
Double Deck Terminal Block	10	$ 1.40	14.00	2002-2201
End plate for Double Deck Terminal Block	1	$ 0.31	0.31	2002-1201
2 pole Terminal Block	5	$ 0.59	2.95	2002-1292
2 Pole Ground Terminal Block	5	$ 2.15	10.75	2002-1292
End Plate for 2 Pole Terminal Block	2	$ 0.30	0.60	2002-1292
4 Position DIN Rail Mount Terminal Block	15	$ 0.94	14.10	2002-1401
End Plate 2mm Thick for Fuse Term Block	1	$ 0.79	0.79	2002-992
Connector Accessory, jumper	10	$ 0.85	8.50	2002-405
Inductive Proximity Sensor	2	$ 18.75	37.50	PNM6-CP-3A
Inductive Proximity Sensor Bracket	2	$ 6.00	12.00	ST12C7W
Rotary Encoder	1			TR3-K5A-0100NV1AOC-F03
Rotary Encoder Bracket	1			176389-01
E-Stop Button	1	$ 40.00	40.00	SSA-EB1P-02

Shelf components Total	442.50
Automation components total	575.94
Total	1,018.44

Table 3: Donated Parts and Total Cost

Donated Parts		
Pneumatic cylinder	2.00BB3MAU14AN-8.00	$ 125.00
Pneumatic cylinder	2.00CF4MAU14AC06.00	$ 114.57
Cart	N/A	$ 100.00
Total Value		$ 339.57
	TOTAL COST ORDER #1	$ 7,524.64
	TOTAL COST ORDER #2	$ 1,018.44
	Donated Parts Worth	$ 339.57
	OVERALL COST	$ 8,882.65

1.3. Appendix C: Turtle Diagrams



Tu-Poc Diagram + Risk Analysis

Suppliers:
- MFP Automation

TIP:
Individual process stakeholders vote on top risks & opportunities to satisfy requirements for (i.e. ISO 9001:2015 clause 4.4.1d, 6.1, etc.)

1 2 3 = Top 3 Risks
1 2 3 = Top 3 Opportunities

Customers:
- MFP Automation

WHAT: Equipment & Materials
- Servo motor
- Aluminum framing to connect to top surface

WHO: Personnel & Competencies
- Single person will need to be there to operate

KEY INPUTS
- Speed of feed
- Size of motor

Process 3:

Servo Motor

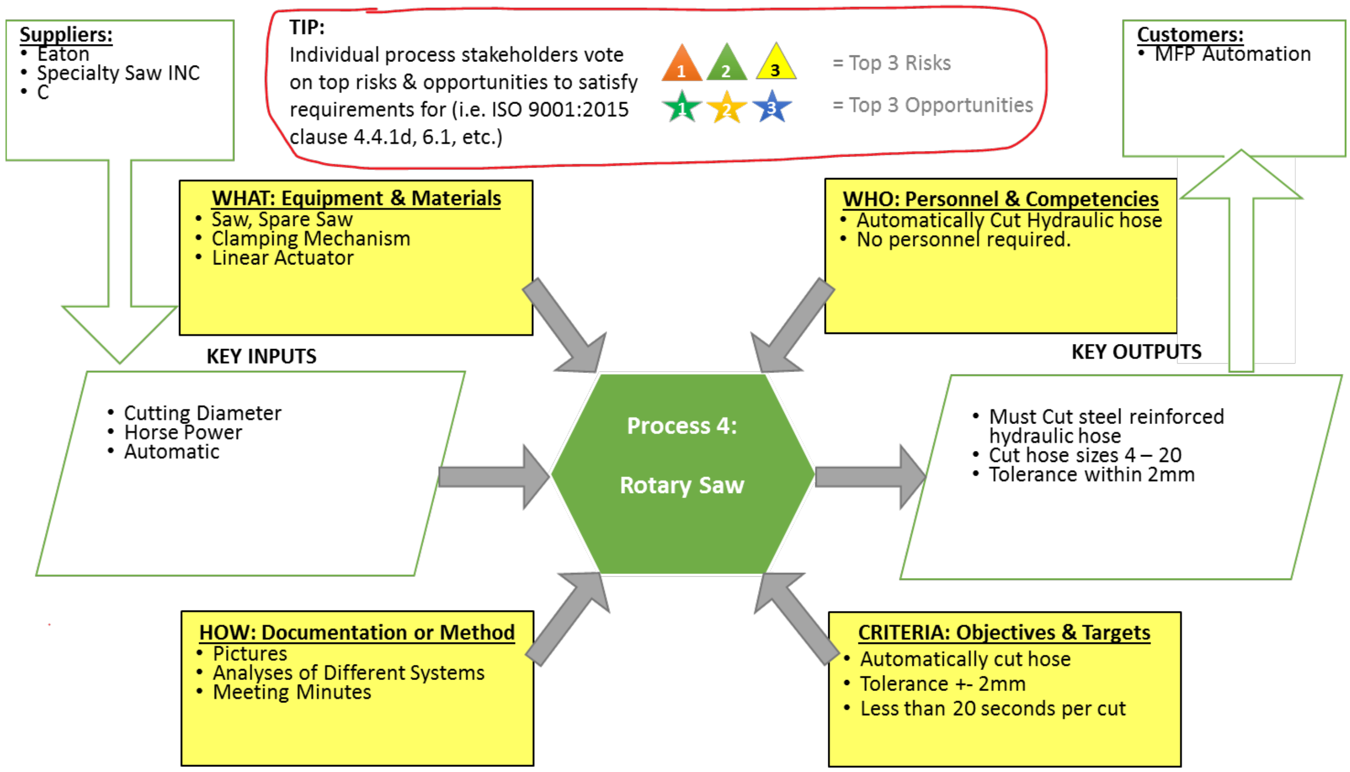
KEY OUTPUTS
- Be able to stop feed at specific length of hose fed to rotary table where it is coiled

HOW: Documentation or Method
- Record how tasks are performed – steps taken to accomplish task
- Record problems that occur
- Pictures

CRITERIA: Objectives & Targets
- Be able to stop when set amount of hose is reached

Concentric

Tu-Poc Diagram + Risk Analysis



Turtle Diagram + SIPOC Diagram = Tu-Poc Diagram

Concentric Tu-Poc Diagram + Risk Analysis

Suppliers:
- MFP Automation

TIP:
Individual process stakeholders vote on top risks & opportunities to satisfy requirements for (i.e. ISO 9001:2015 clause 4.4.1d, 6.1, etc.)

1 2 3 = Top 3 Risks

1 2 3 = Top 3 Opportunities

Customers:
- MFP Automation

WHAT: Equipment & Materials
- Ball & screw linear actuator
- Mounting frame to top surface of the table

WHO: Personnel & Competencies
- Single person will need to be there to operate

KEY INPUTS
- Mounted strongly with ability to not loosen
- Strong enough to move rotary cutter into hose

Process 5:

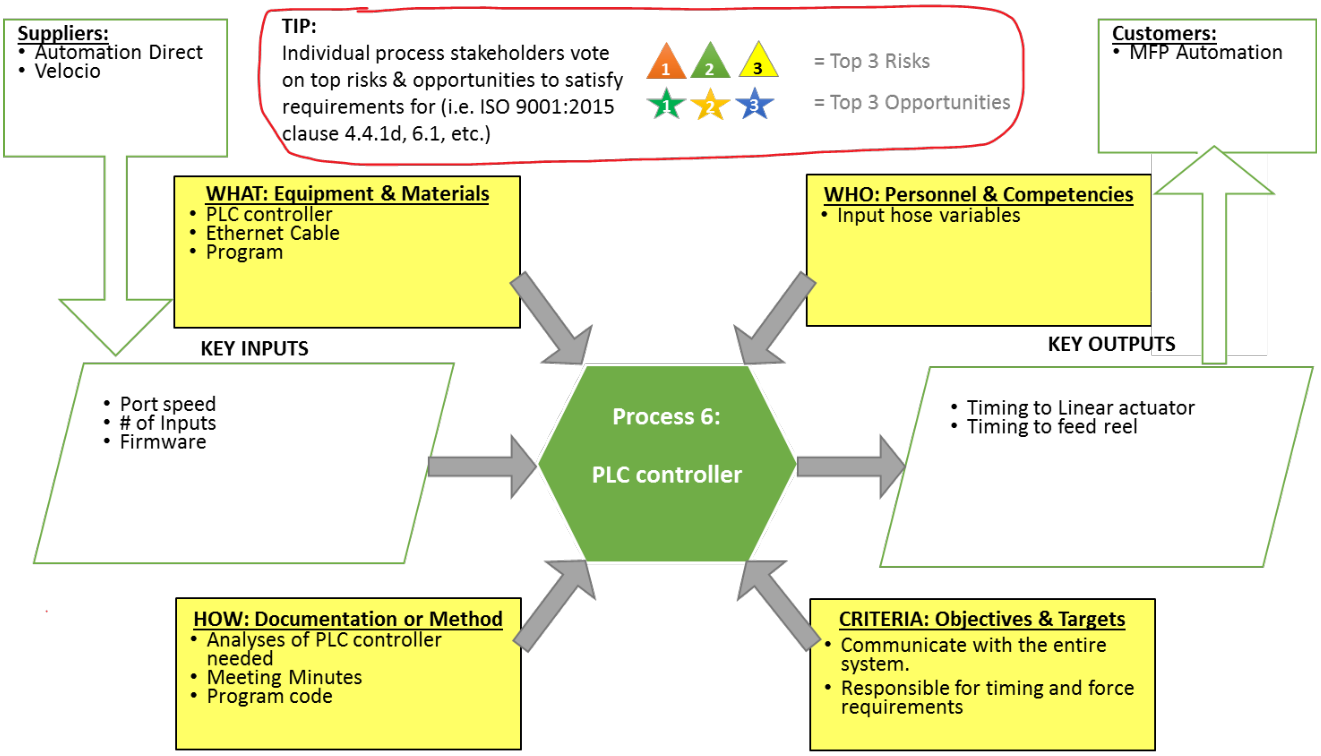
Ball & Screw Linear actuator

KEY OUTPUTS
- Easy ability movement mechanism into the hose for cutting purpose

HOW: Documentation or Method
- Record how tasks are performed – steps taken to accomplish task
- Record problems that occur
- Pictures

CRITERIA: Objectives & Targets
- Easy movement ability into hose for purpose of cutting hose

Tu-Poc Diagram + Risk Analysis



Tu-Poc Diagram + Risk Analysis

Suppliers:
- Marken
- Constructed ourselves.

TIP:
Individual process stakeholders vote on top risks & opportunities to satisfy requirements for (i.e. ISO 9001:2015 clause 4.4.1d, 6.1, etc.)

1 2 3 = Top 3 Risks

1 2 3 = Top 3 Opportunities

Customers:
- MFP Automation

WHAT: Equipment & Materials
- Pulley *2
- Torque Motor
- Roller Guides

WHO: Personnel & Competencies
- Set hose from new reel into the system.

KEY INPUTS
- Size of Reel
- Weight of Reel
- Angle/radius of factory reel to transfer reel.

Process 7:

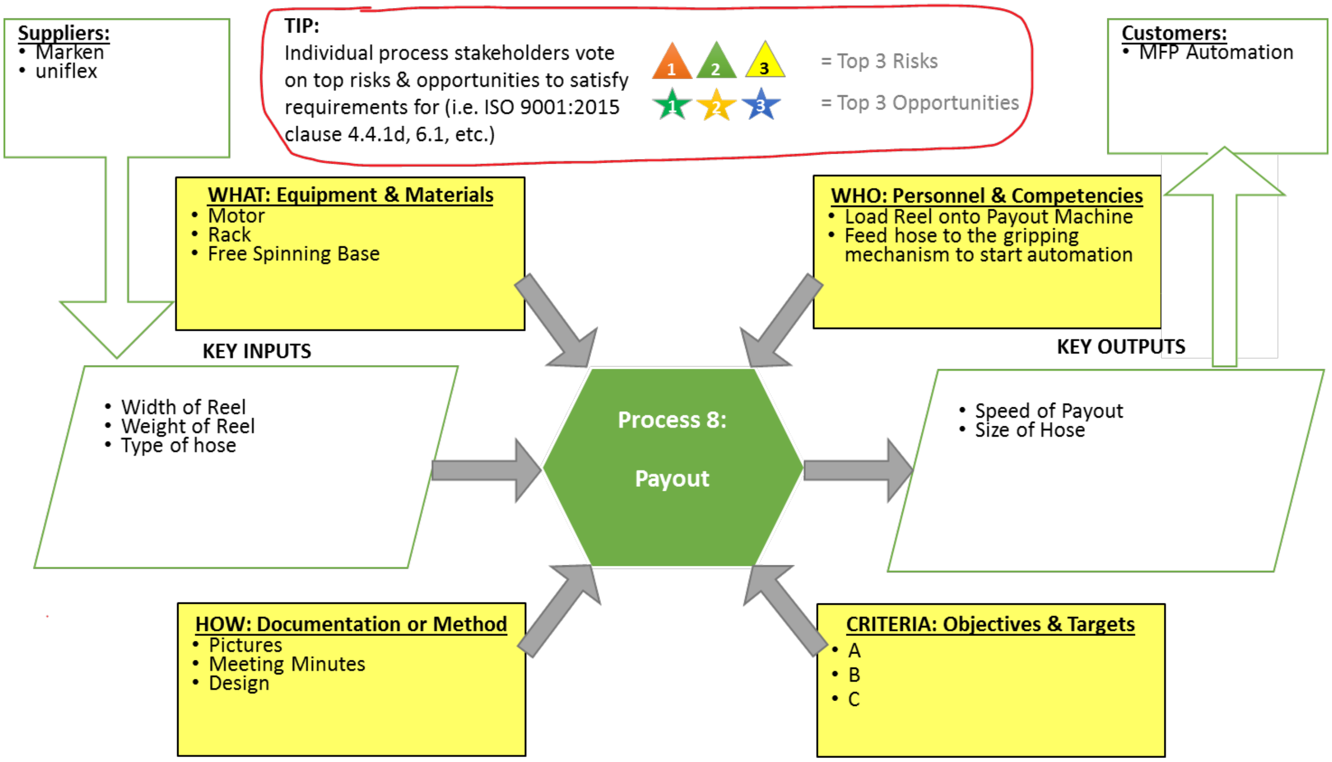
Tensioning System

KEY OUTPUTS
- Torque required
- Speed of motor
- Amount of slack in system

HOW: Documentation or Method
- Meeting Minutes
- Pictures
- Research

CRITERIA: Objectives & Targets
- Tension the cable to reduce elastic recovery to arched shape
- Produce slack in the system

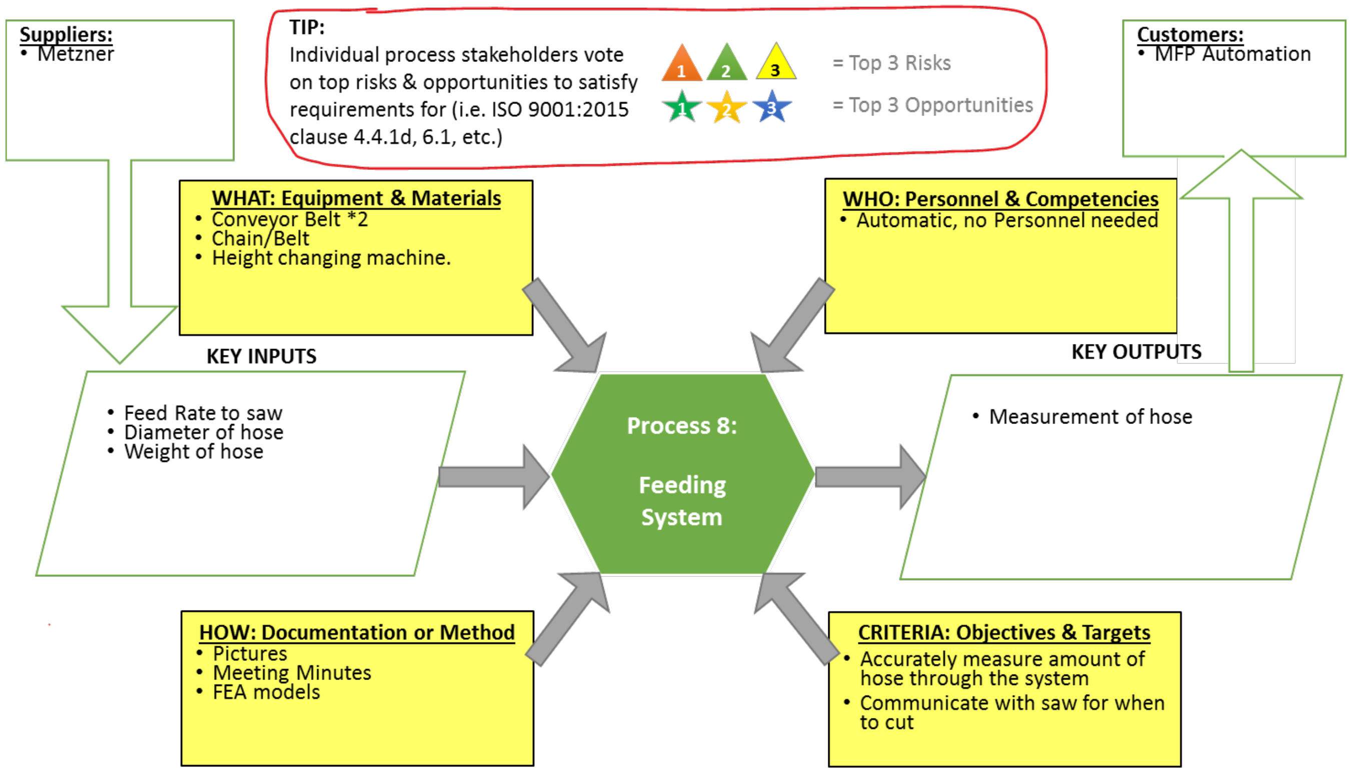
Tu-Poc Diagram + Risk Analysis



Turtle Diagram + SIPOC Diagram = Tu-Poc Diagram

Concentric

Tu-Poc Diagram + Risk Analysis



Turtle Diagram + SIPOC Diagram = Tu-Poc Diagram

1.4. Appendix D: Uniflex quote

The best Return on Investment
Since 1972

UNIFLEX

UNIFLEX of America LLC.
1088 National Parkway
Schaumburg, IL 60173

Phone: (847) 519 1100
Fax: (847) 519 1104
E-Mail: sales@uniflexusa.com

Machines for the Manufacture of Hose Assemblies

Michigan Fluid Power
Roger Betten Jr
4404 Central Parkway

Hudsonville, MI 49426
United-States

Prepared by:
Bryan Xu

Proposal / No. XRPUQ1811

Dear Roger ,

10/24/2017

Thank you for your interest in our products. Please find below the quotation for your requested items.

Uniflex machines are grease free providing exceptional life, clean production, operator safety and ease of use, reduction in costly maintenance and delivers consistent performance, all adding up to the best return on investment in the industry.

Fixed six o'clock die for improved ergonomics in the assembly of large bore assemblies decreasing scrap while increasing productivity and safety of the operators.

Pos.	Description	Qty	Unit Price	Price
1	EM 6.2 P hose cutting machine (220-240V-50/60Hz-3Ph) Feed of the hose is pneumatic For use in seriel production up to 1.25" SAE R13 and SAE R15 hose OK to use in some intermittent production for up to 2" SAE R13 and SAE R15 hose Can also do 2" industrial hose Uses TM C 350x3x30 cutting blade CE Safety certified NOTE: Many voltages are available and must be specified at the time of the order. Prices for non standard voltages could have a price increase to above quoted prices.	1	$4,935.00	$4,935.00

Pos.	Description	Qty	Unit Price	Price
2	EM 115.3_MVA hose cutting machine (220-480 V-50/60Hz-3Ph) Pneumatic feed of the hose into the cutting blade Speed of the feed is adjustable For use in seriel production up to 2" SAE R13 and SAE R15 hose OK to use in some intermittent production for up to 3" SAE R13 and SAE R15 hose Can also do 3" industrial hose Uses TM C 520x4x40 cutting blade Has brake motor to slow blade quickly for safety CE Safety certified NOTE: Many voltages are available and must be specified at the time of the order. Prices for non standard voltages could have a price increase to above quoted prices.	1	$9,758.00	$9,758.00
3	UWT 2.1_22_23 - Electric winding table with foot pedal 230V 50Hz single phase Electric driven hose coiling reel with foot pedal control for easy winding and unwinding of hoses up to 1 1/4" LxWxH = 800x900x1600 mm	1	$3,197.00	$3,197.00
4	UMS 4 Hose length measuring device Use with Uniflex floor mounting stand 514.1 for ideal height and stability Also can be mounted to bench or table	1	$805.00	$805.00
5	514.1 Floor stand for UMS 4 (840 mm)	1	$203.00	$203.00

Prices are in addition to our terms of payment and delivery.

validity of offer: 30 days
FOB: Schaumburg, IL
Payment Terms : 50% down, Net 30 days for remaining balance

delivery time: 1-12 weeks

State Sales and Use Tax will be charged to customers within the U.S. unless a Tax Exemption Certificate is provided.

An international buyer of these goods is responsible for all export taxes, duties and brokerage fees that may apply.

We would be pleased, if this quotation meets your requirements. In case of any further questions, please do not hesitate to contact us.

Best regards,

Bryan Xu
Uniflex of America
Cell: 847-436-0403

Uniflex EM 115.3

- Pneumatic feed of the hose into the cutting blade
- Speed of the feed is adjustable
- Has brake motor to slow blade quickly for safety
- CE Safety certified
- Can cut up to 2" of steel reinforced hydraulic hose
- 220-480 Volts 3phase power
- Must be used with additional component called UMS 4, which is a hose length measuring device

Metzner CCM 4

- Electric conveyor feeding system
- Speed of feed is adjustable
- Can cut 1 ¼ " of steel reinforced hydraulic hose
- 3-400 Volts 3phase power
- Includes length measuring system

1.5. Appendix E: Final CAD Design

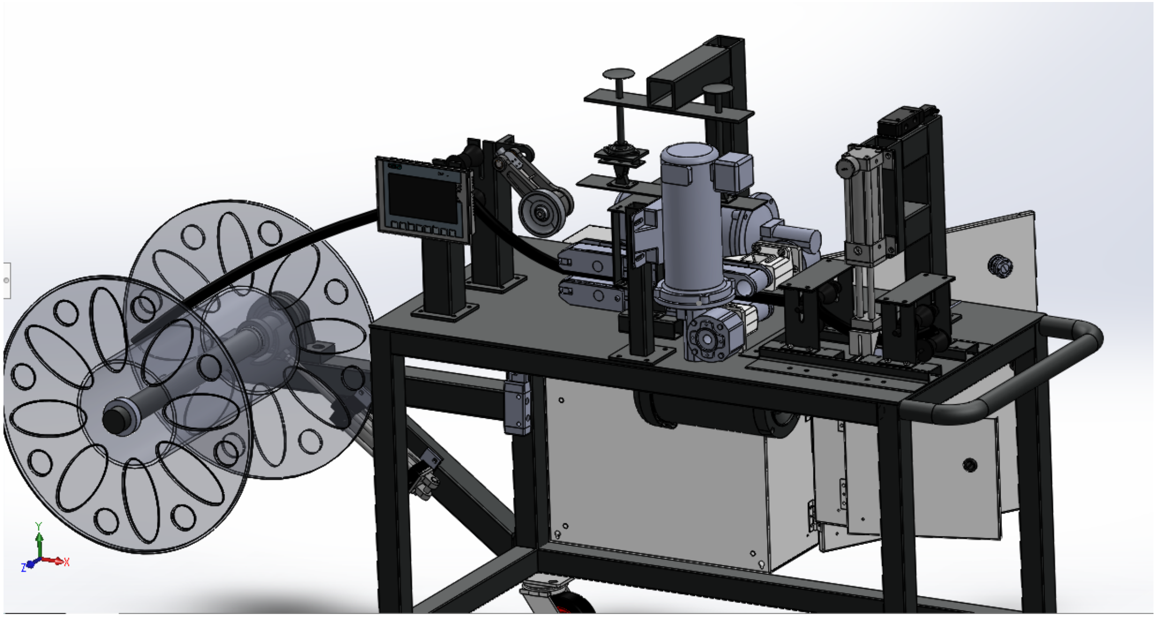


Figure 1: Full Cart Design Front View – done with Solid Works

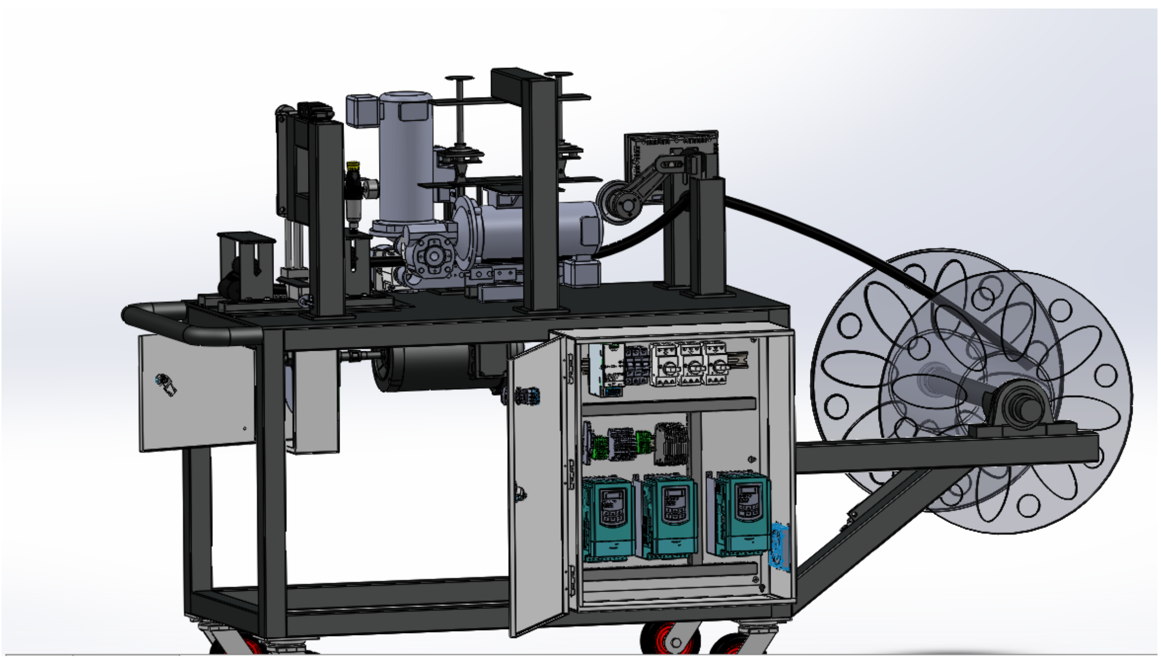


Figure 2: Full Cart Design Rear View – done with Solid Works

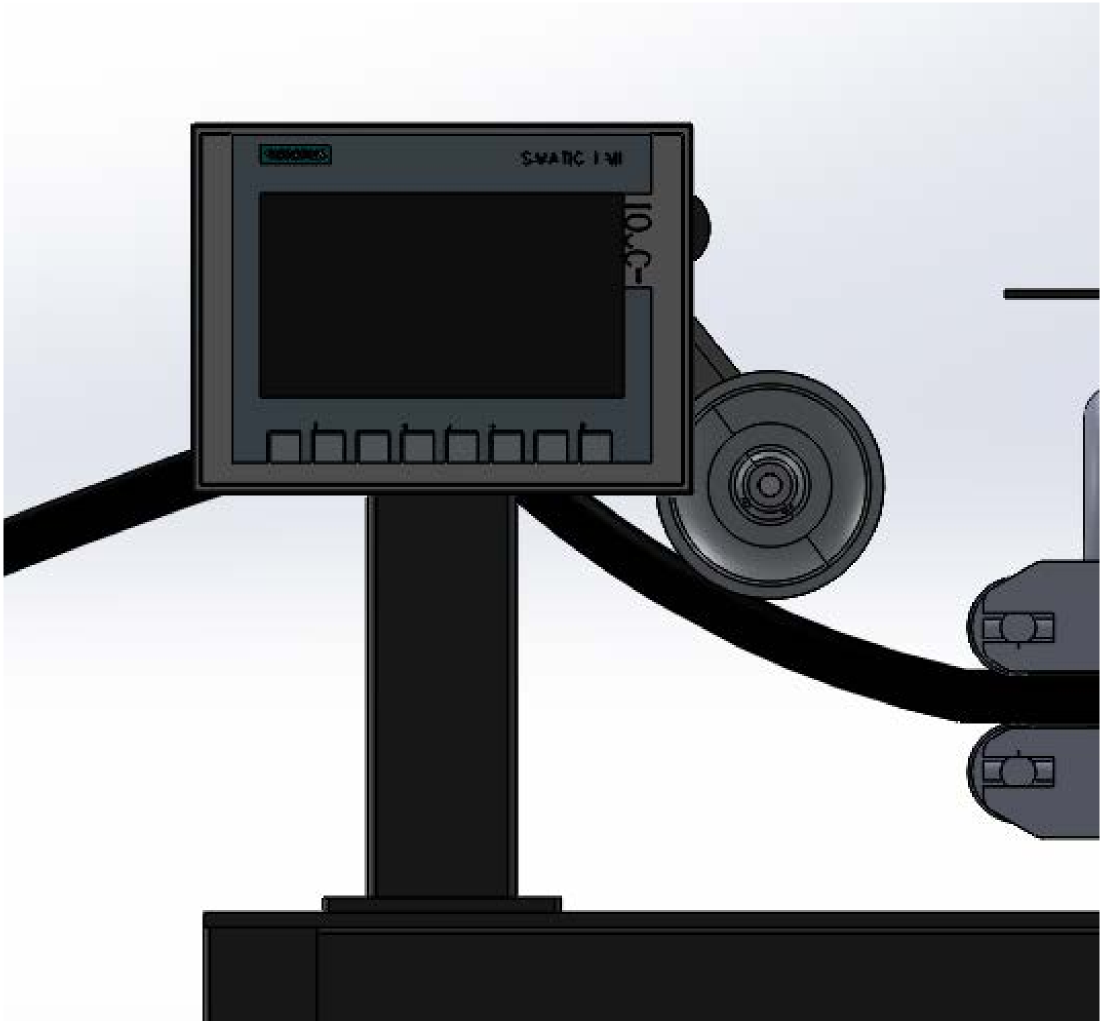


Figure 3: Measuring system showing PLC and Rotary Encoder– done with Solid Works

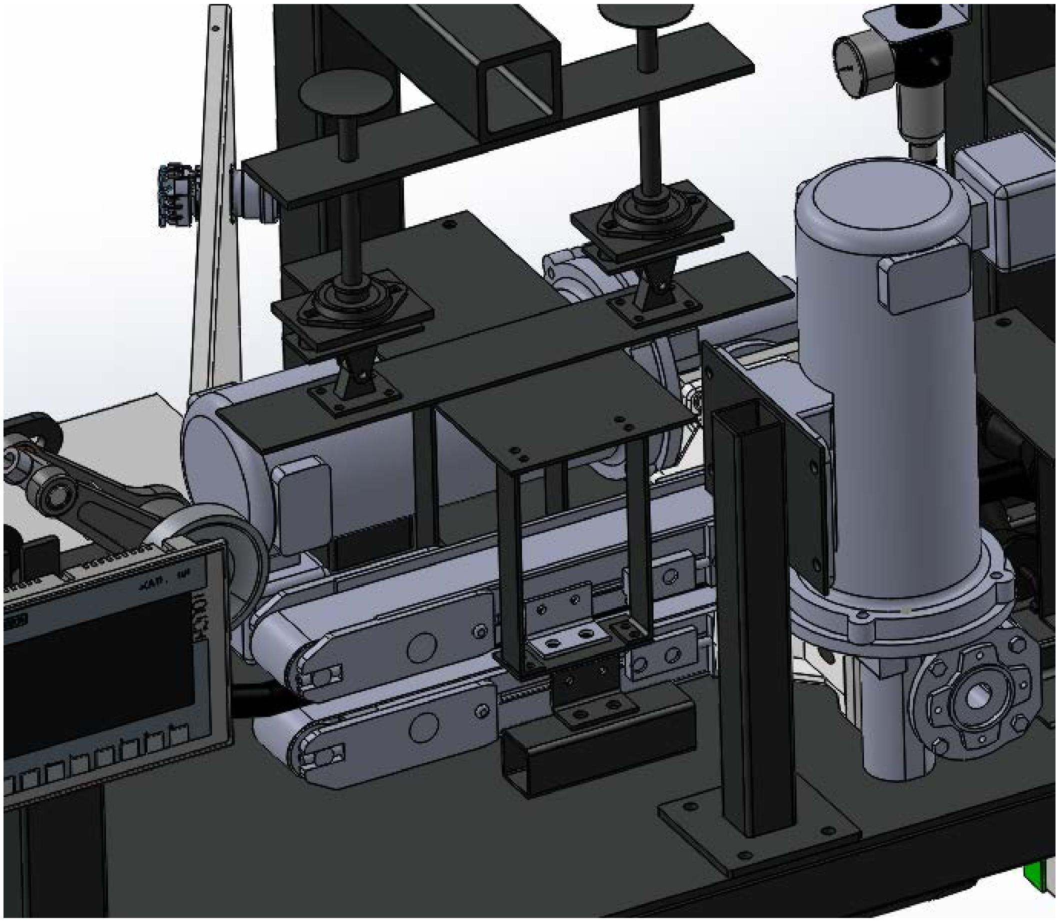


Figure 4: Conveyor Design– done with Solid Works

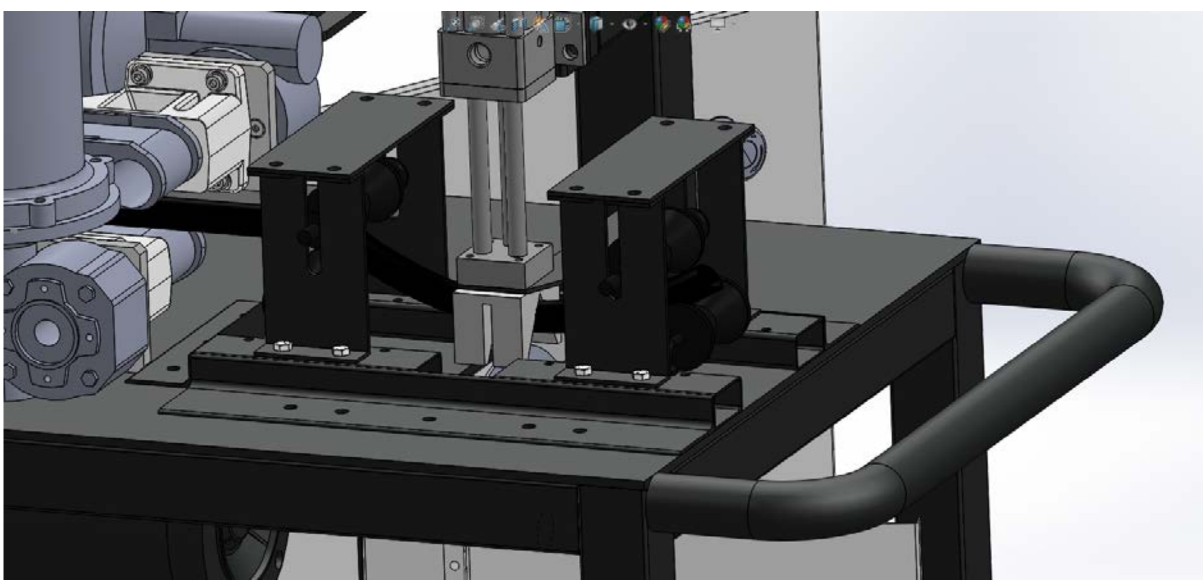


Figure 5: Blade Guard Design for Cutting system– done with Solid Works

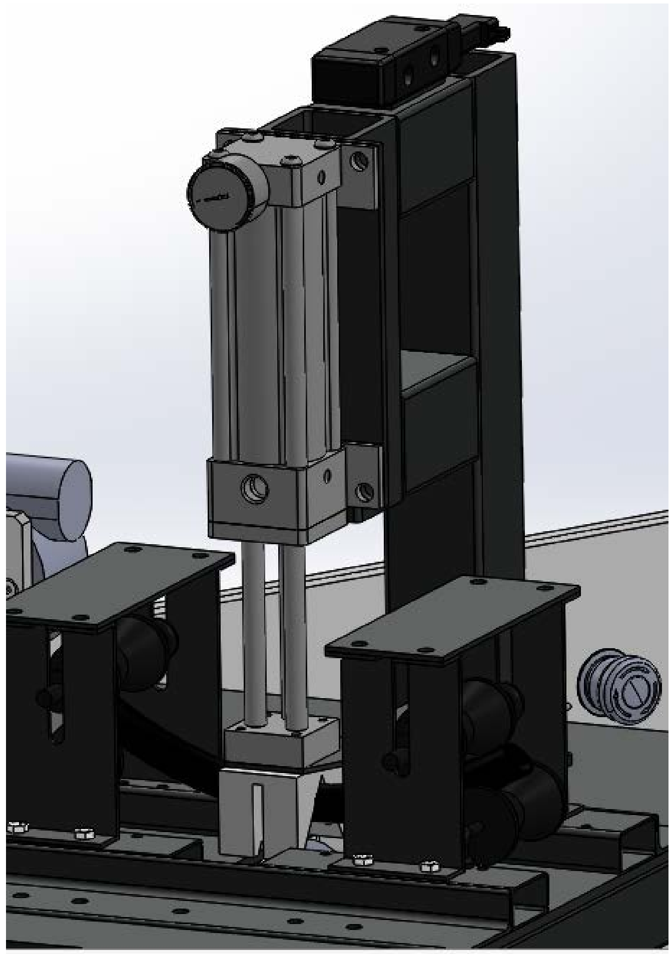


Figure 6: Pneumatic Design for Cutting System– done with Solid Works

1.6. Appendix F: Fabrication of Project

Figure 1: MFP employee Tim Beute Plasma Cutting the Blade Slot.

Figure 2: Team leader Peter Betten Mounting Blade Enclosure and Saw.

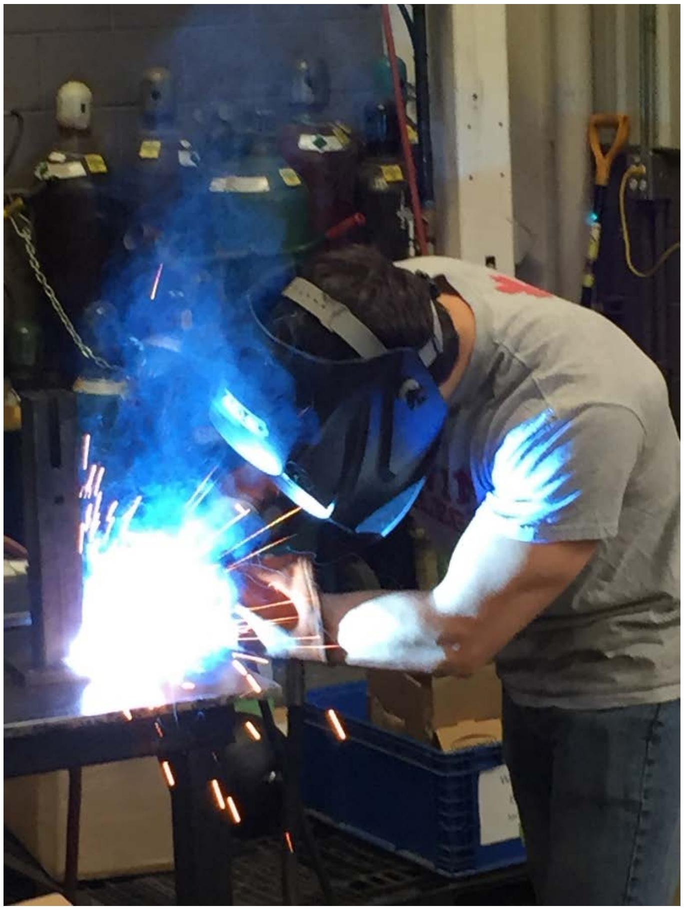


Figure 3: Team leader Peter Betten welding mounts for the tensioner system.

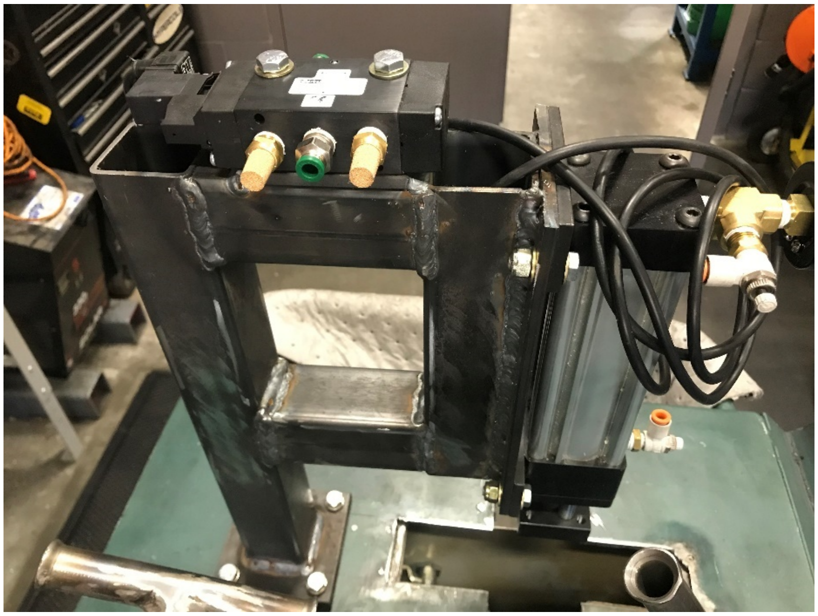


Figure 4: Cutting System Mounted.

Figure 5: Spool Mount Fabricated with Jam Brake and Bearing.

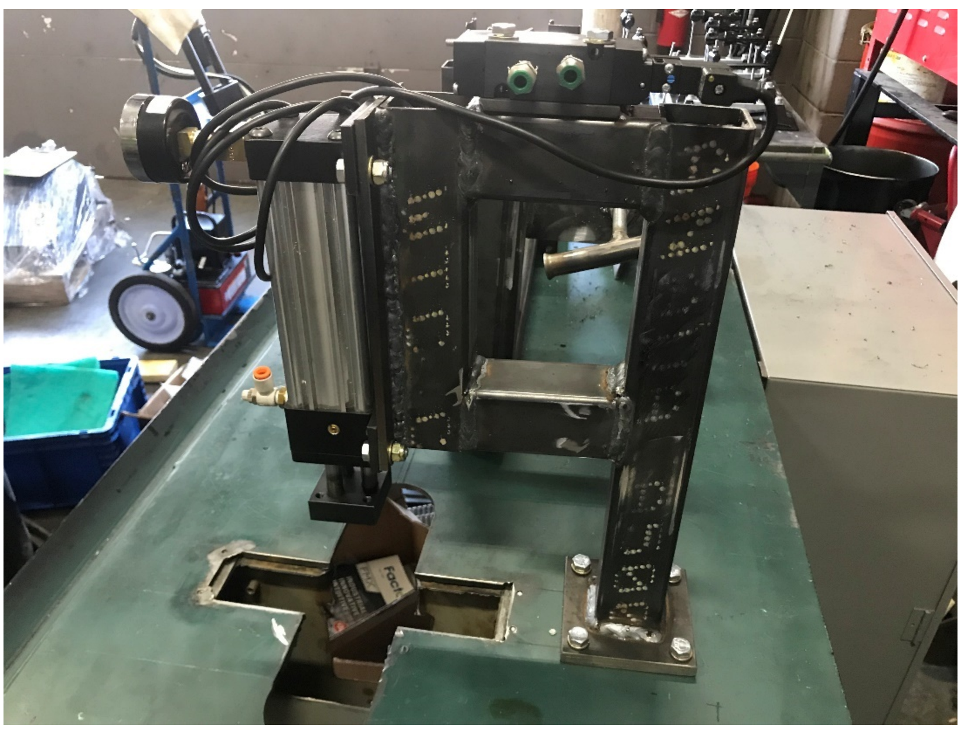


Figure 6: Overview of Top of the Table, with the pneumatic cylinder and stand for the cutting system.

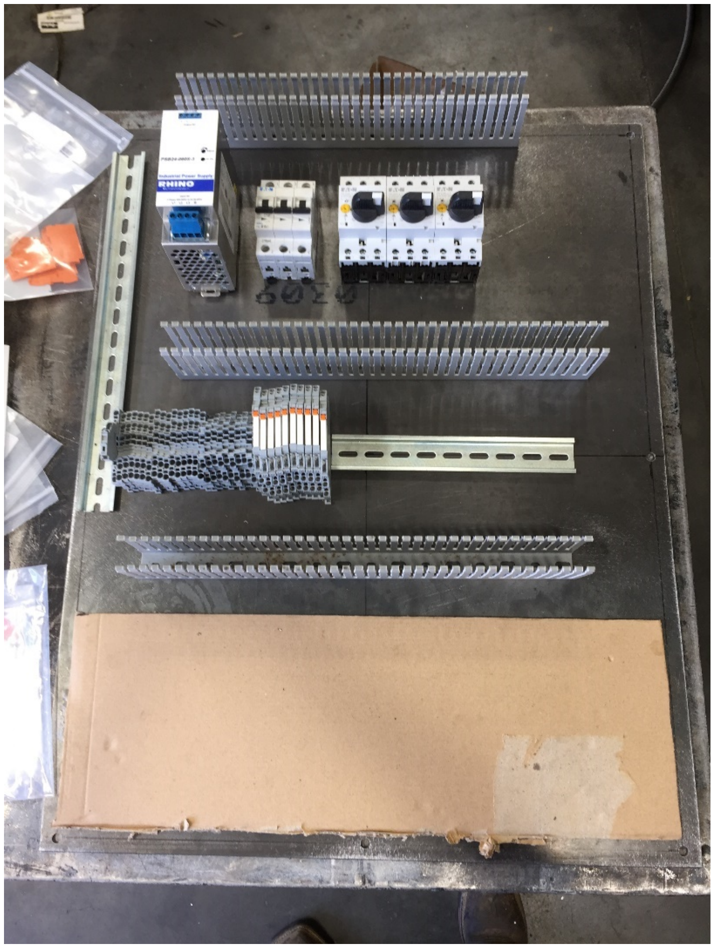


Figure 7: Preliminary lay out of the Sub panel for the Electrical Enclosure.

Figure 8: Entire Cart Ground down for Painting.

Figure 9: Team member Mitchell DeBruin prepping the cart for painting.

Figure 10: Conveyor Mount being fitted, while head with an overhead crane.

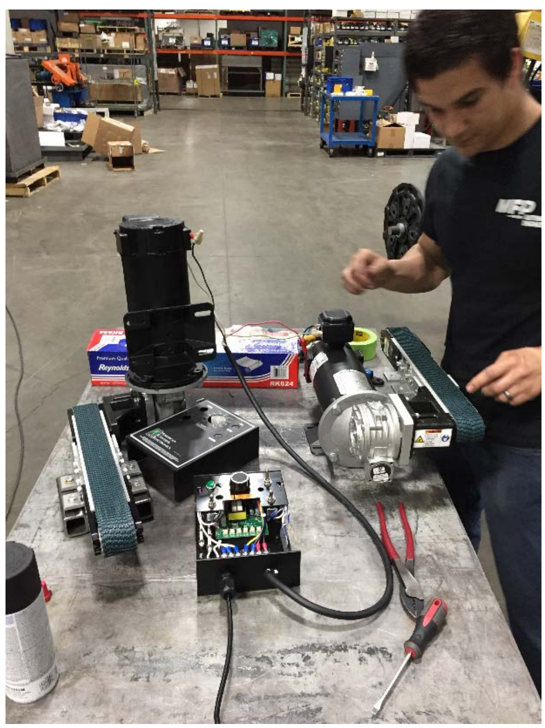


Figure 11: Team leader Peter Betten wiring up the conveyors for testing.

1.7. Appendix G: Final Project Prototype

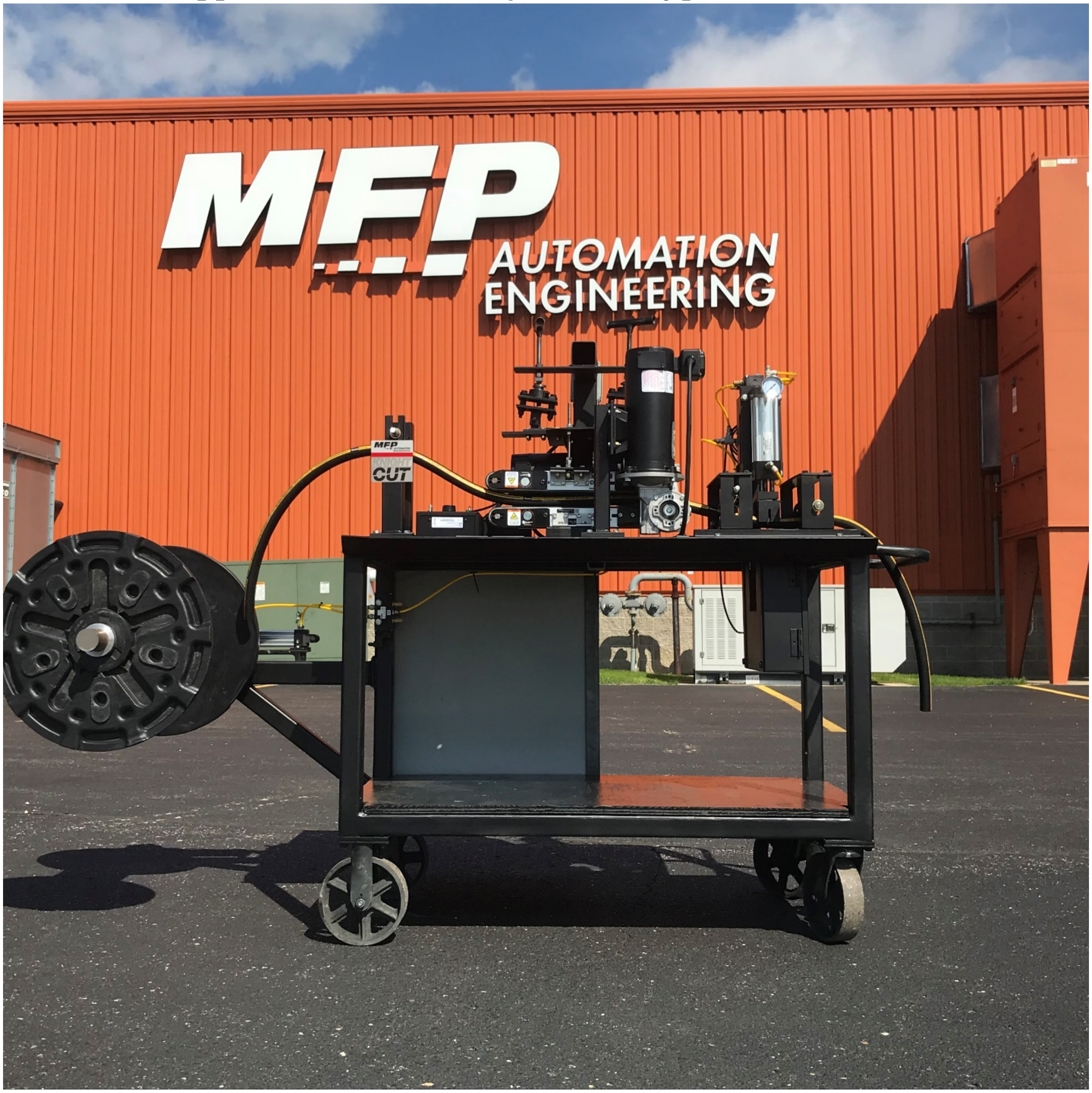


Figure 1: Head on View of Knight-Cut

Figure 2: Isometric View of Knight-Cut

Figure 3: Back Side of Knight-Cut

Figure 4: Front View Knight-Cut

1.8. Appendix H: Controller

Code:

```
PROGRAM PLC_PRG

VAR

    Wait: TON;

    begin: BOOL;
```

```
        time1: TIME;
        out: BOOL;
        et: TIME;
        Start: BOOL;
        count: INT;
        Stage: INT;
        length: INT;
        Conveyor: BOOL;
        HydrAct2: BOOL;
        inleng: INT;
        Blade: BOOL;
        HydrAct: BOOL;
        Prox: BOOL;
        HydrDea: BOOL;
        incount: INT;
END_VAR
(*IF EncoderA = TRUE AND EncoderA <> PrevA THEN; // tick up length on rise edge
        EncoderA := PrevA;
        IF      EncoderB = FALSE THEN;
                length := length + 1;
        ELSE;
                length := length - 1;
        END_IF;
END_IF;*)
Wait(IN:= begin, PT:=time1 , Q=>out , ET=>et);
IF Start = TRUE THEN;
        begin := FALSE;
        out := FALSE;
        count := 0;
```

```
        Stage := 0;
        Stage:= Stage + 1;
END_IF;
IF Stage = 1 THEN;
        length := 0;
END_IF;
IF Stage = 1 THEN;
        Conveyor := TRUE;//ramp up conveyor motor
        HydrAct2:= FALSE;
        IF count = 0 THEN; // tick before ramp down
                time1 := INT_TO_TIME(inleng / 45+5);
                begin := TRUE;
                (*IF Length = inleng + 2  THEN; // for intial pull
                        Stage:= Stage + 1;
                END_IF*)
        ELSE;
                time1 := INT_TO_TIME(inleng / 45);
                begin := TRUE;
                (*IF Length = inleng - 2  THEN; // for the res of the pulls
                        Stage:= Stage + 1;
                END_IF*)
        END_IF;
        IF out = TRUE THEN;
                Stage:= Stage + 1;
        END_IF
```

Figure 1: HMI home screen